RESEARCH ARTICLE

Shortest Power Flow Paths in Deregulated Scenario Using Graph Theory

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ABSTRACT: In the perspective of the emerging smart grid concept, the future distribution networks involves the distributed generations. In vertically integrated system the operator was responsible for the system in balance, to ensure that the production and imports continuously match the consumption and exports. Distribution system planning with distributed generation work perfect with future grid. Thus system has to undergo a process of transition and restructuring to provide low cost electricity to everyone. The restructuring process involves separation of transmission activity by generation activity, by introducing competition in generation activity through creation of power pool in spot electricity market. Efficient management of networks required a shortest route power flow from one point to another. It is often necessary to determine alternative routes through the network in deregulated electricity market. The aim of this work is to apply Dijkstra's Algorithm to determine the optimal path for power flow in deregulated environment.

KEYWORDS: Deregulated electricity market, shortest path power flow, Graph theory, Dijkstra's algorithm

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1. INTRODUCTION

In most of the developing countries, the growth of the power sector was under the direct supervision of their respective federal governments. They held the sole responsibility on all fronts such as making investment decisions for new power projects, providing for budgetary support within their annual plan outlays, setting the operating guidelines for their generators and transmission systems, and finally setting the prices for the customers. Distribution system planning with distributed generation and automation is important in deregulated electricity market to providing uninterrupted power to the consumers connected to the network with less cost. Efficient management of network follows strategic planning. The distribution network topology is becoming dynamic thus containing several routes for power flow. Many source of power generation by the individual power produces. Opening up the electricity sector to competition is an important tool to improve the efficiency of power generation and thereby to benefit consumers. The vertically integrated utilities could recover their costs regardless of whether they operated efficiently or not. However, with the introduction of competition, there has been an important shift from this approach. Producers have ceased to be protected by their exclusive rights to generate and supply electricity [1].

An efficient distribution system restoration strategy to quickly determine and optimize restoration plans can significantly reduce the overall customer outage time, thereby enhancing customer satisfaction. It is often necessary to determine alternative routes in the network for power flow when more source of power generations [2]. The Independent System Operator is an entity entrusted with the responsibility of ensuring there liability and security of the entire system. In order to maintain the system security and reliability, the Independent System Operator procures various services such as supply of emergency reserves, or reactive power from other entities in the system. The most benefits of deregulated structure to get electricity at low prices as industry participants compete to secure purchase of their electricity and services. The benefits of deregulation are cheaper electricity, efficient capacity expansion planning ,pricing is cost reflective rather than a set tariff ,Cost minimization, More choice for better service and more Employment options. The advantages of this algorithm is graphical representation of power flow in the electrical network this will helps to initial planning for identification of shortest path power flow and also planning of distribution network.[3,4].

1.1 Problem Statement

In the deregulated electricity market many power individual power producers will compete in the power trading [5]. Competitive markets provide the driving force for generators to innovate and operate in the most efficient and economic manner in order to

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remain in the business and recover their costs [6]. The competitive electricity market thereby offers customers and industry participants a range of benefits. Many sources of power generation, several route of power flow this make distribution network more composite. The objective of this work is to reconfigure the network and find the optimal path in the power system network to enhance the power system reliability [7] using Dijkstra's algorithm. This is one of the well known for optimal path selection in the network, and that have been used and implemented in several applications and in several approaches.

1.2Graph Theory

The main reasons for the application of graph theoretic methods in this research include: (i) power networks are naturally modeled as graphs, (ii) topology constraints of power networks can be handled by graph theoretic algorithms, (iii) well designed graph theoretic algorithms provide better solutions than local suboptimal solutions, (iv) well developed and efficient graph-theoretic algorithms are powerful tools for the solutions of combinatorial problems, (v) the data structure for graph and network programming techniques can facilitate the implementation of graph theoretic algorithms. Therefore this algorithm has a lot of use and as well as more benefits. Dijkstra's algorithm is shortest route algorithm that considers the determination of the minimum cost (distance) from an origin to a destination through some connecting links. The approaches of Dijkstra's search that computes the shortest paths from the start node to all other nodes in the graph. For every node, it computes and stores the minimum cost to the start node and the previous node on the optimal path. By tracing back to the previous node, it is possible to generate the optimal path. [8]

2. METHODOLOGY

In modern power distribution networks, maximizing the efficiency of the entire system as a whole is extremely difficult. To solve the global optimization problem of such a complex network in terms of overall systems control, this method proposes an efficient distributed control method for future grid focusing on tie-set graph theory, where a tie-set is a set of all the edges in a loop of a graph. On the basis of tie-set graph theory, global optimization of an entire network can be realized as a result of local optimization in n-dimensional liner vector space, where n is the nullity of the underlying graph of a power network the amount of power, which is the algebraic sum of power production, consumption, inflow, and outflow monitored. Power flow on a link between two nodes is defined as an edge flow, to realize efficient power management. We employ the notion of tie-sets that reduces the complexity of the power flow loss problem by dividing a power network into a set of loops that forms a linear vector space on which the power loss problem.

A graph G = (V, E))is defined as a tie-set graph, where a set of vertices (nodes)V corresponds to a fundamental system of tie-sets{ L_1,L_2,L_3,……..L_n} and a set of edges (links) E corresponds to set of edges {e(L_i, L_j)}, (i ≠ j), which represents the connection among the tie-sets. Where (a,b,c,d,……) are the consumer nodes or smart meters. Where power inflow and outflow is recorded. Each consumer excess power feed to the grid and when ever required they can take it from the grid.

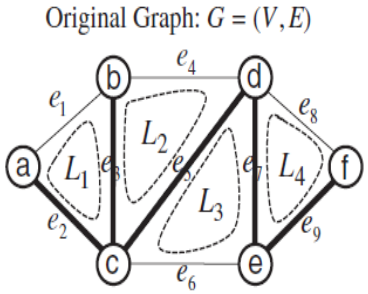


Fig 1. Graph of the bus

The objective of this proposed method is to find the shortest path in power system network. The application of Graph theory to the distribution networks made easy to find the minimum loss path in the composite network. Generating station is considered as source node, distribution lines are considered as path, and impedance of the line is considered as weight on the path from source to destination.

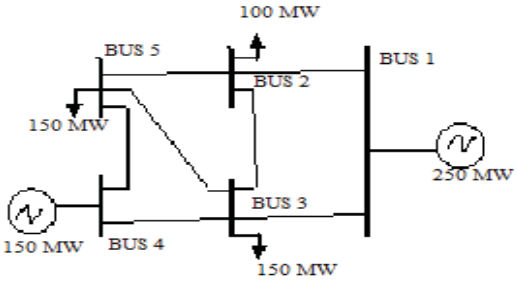


Fig 2. IEEE 5 bus system

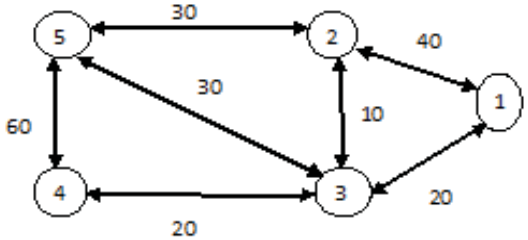


Fig 3. Oriented graph with line impedance

The IEEE-5 bus system is converted using graph theory as an oriented graph with line impedance between the buses. Node1 is acting as source node and node 5 is acting as destination node. By using the shortest path algorithm it is possible find the minimum impedance path for power flow. This may reduce the line losses and minimum path of power flow. The Dijkstra's Algorithm is suitable for identifying shortest path in multiple feeder system. Since Dijkstra's algorithm finds solution in the single pair shortest path problem, we select node 1 as source and node 5 as destination [9]. Shortest path algorithm will identify the path between source and destination. Source node 1 to destination node 5 the path for power flow is 1-3-5 and impedance of that line is 50ohms.

3. RESULTS AND DISCUSSION

The simulation is done in MATLAB 2014 in graph theory function. The line data are stored in the excel sheet and they are imported in the MATLAB program. The program is written for infinite buses and any number of buses data can be used for simulation and identifying the shortest path. In this paper IEEE 6 and 11 buses system are simulated and results are as shown below.

Case Study-1

In this case study IEEE- 6 bus data are taken for the simulation resistance and reactance of the lines. The shortest path between 1 to 5 is 1-6-5 impedance of line is 0.8324 ohms. Similarly between 4 to 5 is 4-6-5 with line impedance of 0.7432 ohms. The shortest path highlighted in the results.

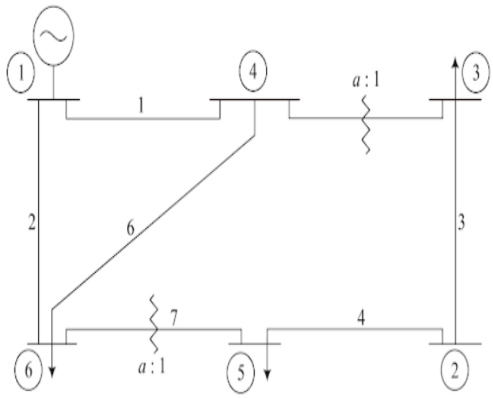


Fig 4. IEEE 6 bus system

Table 1: System Data and Parameters for 6-Bus Distribution Network

Source Node i	Destination Node j	Resistance Ohms	Reactance Ohms	Line impedance Ohms
1	4	0.08	0.37	0.3785
1	6	0.123	0.518	0.5324
2	3	0.723	1.05	1.2748
2	5	0.282	0.64	0.6994
4	3	0.0	0.133	0.1330
4	6	0.097	0.407	0.4184
6	5	0.0	0.3	0.3000

Simulation Results

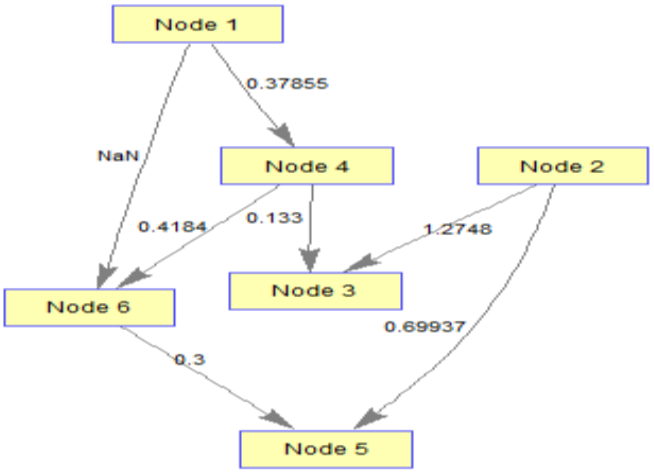
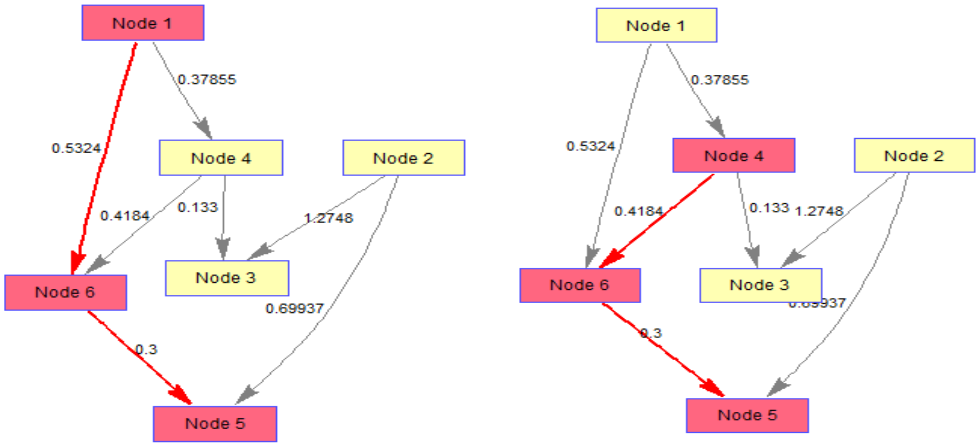


Fig. 4 Simulated Results of Oriented Graph with Line Impedances



a. shortest path 1 to 5 **b. shortest path 4 to 5**

Fig. 5 a & b: Simulated Results of Shortest Path different source and sink in netwrok

Line loss calculations

Line Losses = I^2* Z ----(i), where, I is Current (PU), Z is Impendence (PU)

Table 3: Shortest Path with line losses For 6-Bus Distribution Network

Shortest Path	Source Node to Destination Node	Optimal Path	Losses in PU
First	1 to 5	1 - 6 – 5	0.8324
Second	4 to 5	4 - 6 – 5	0.7432

Case Study 2

In the 2nd case study IEEE-11 bus data is taken for the simulation whose line resistance and reactance are taken to calculate the line impedance between the source and destination node. Line impedance between each node is tabulated in the Table 4.

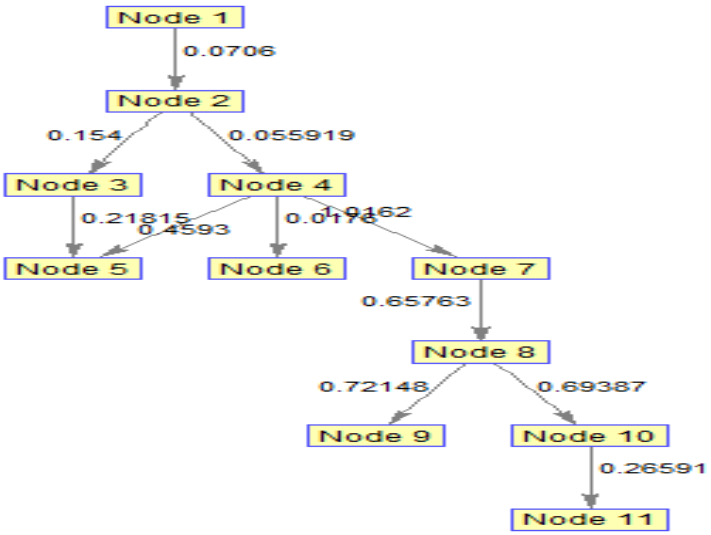
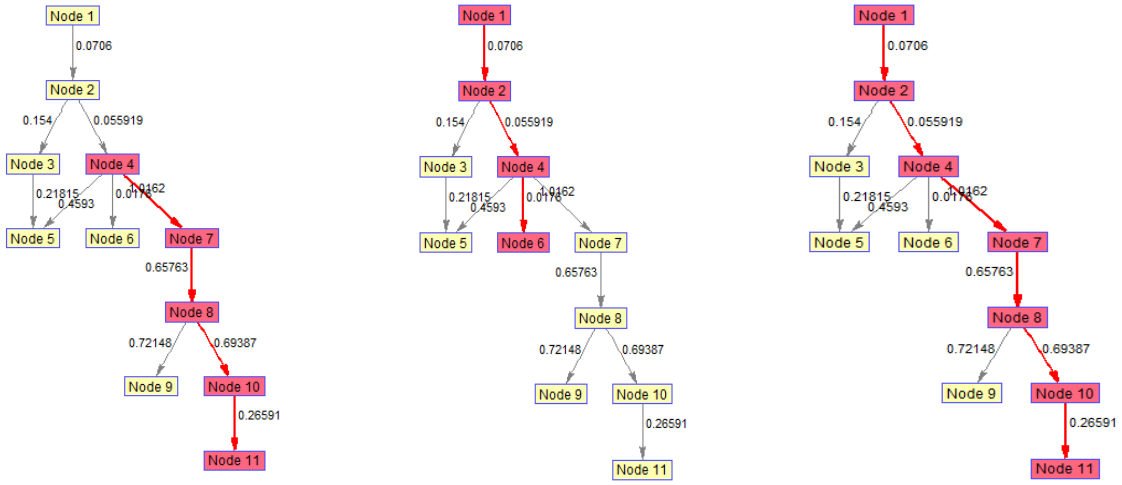


Fig.6. IEEE 11- Bus Distribution System

Table 4: System Data and Parameters for IEEE 11-Bus Distribution Network

Sl. No.	Source Node i	Destination Node j	Resistance Ohms	Reactance Ohms	Line Impedance in Ohms
1	1	2	0.002	0.0706	0.070628
2	2	3	0.003	0.154	0.154029
3	2	4	0.0377	0.0413	0.055919
4	3	5	0.1228	0.1803	0.218147
5	4	5	0.004	0.4593	0.459317
6	4	6	0.0024	0.0176	0.017763
7	4	7	0.6114	0.8117	1.016202
8	7	8	0.6209	0.2167	0.657629
10	8	9	0.0718	0.7179	0.721482
11	8	10	0.4097	0.56	0.693869
12	10	11	0.0264	0.2646	0.265914

Simulation Results of IEEE- 11 Bus Systems



a) Shortest Path 4 to 11 **b)**Shortest Path 1 to 6 **c)** Shortest Path 1 to 11

Fig. 7: Simulated Results of Shortest Path

The simulation results show the shortest path power flow between source and destination node. This algorithm is implemented on any numbers of buses. All the bus data are stored in the excel file that can be imported in MATLAB-2014 version.

4. CONCLUSION

In this paper Dijkstra's algorithm is implemented in deregulated electricity market, many route of power flow due competition amount the power produces in electricity market. To provide the power flow solution in the network dijkstra's algorithm was more suitable for identifying shortest route within the network with minimum line losses. Results shows shortest path with different source and sinks in the network. With graph theory approach it is possible to find out the minimum cost and optimal path for the power flow, hence improves the operational efficiency and uninterruptable power supply to consumers. This algorithm can be implemented for any complex electric network. The simulation is done with MATLAB-2014 graph theory function.

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